CLAIMS

What is claimed is:

1. An apparatus, comprising:

- an integrated circuit (IC) die including a substrate formed with a first semiconductor material;

- a cooling device formed with a second semiconductor material and directly bonded to the substrate of the IC die; and

- the cooling device having embedded therein a plurality of interconnected liquid-conducting passages.

2. The apparatus according to claim 1, wherein the first and the second semiconductor materials are silicon.

3. The apparatus according to claim 2, wherein the cooling device further includes a liquid inlet fluidly coupled to the plurality of liquid-conducting passages and a liquid outlet fluidly coupled to the plurality of liquid-conducting passages.

4. The apparatus according to claim 3, wherein the cooling device further includes a cooling plate having a first and a second cooling plate side with a plurality of interconnected channels being formed in the first cooling plate side; and an enclosing plate mounted to the first cooling plate side to enclose the plurality of interconnected channels and to form the plurality of liquid-conducting passages.

5. The apparatus according to claim 4, wherein the enclosing plate comprises the substrate of the IC die; the first cooling plate side is directly mounted to the substrate of the IC die by a silicon-to-silicon bond; and the liquid inlet and liquid outlet are formed in the cooling plate and extend between the plurality of interconnected channels and the second cooling plate side.

6. The apparatus according to claim 4, wherein the enclosing plate comprises a cover plate; and the second cooling plate side of the cooling plate is directly bonded to the substrate of the IC die by a first silicon-to-silicon bond.

7. The apparatus according to claim 6, wherein the first cover plate side is attached to the first cooling plate side to form the liquid-conducting passages; and the liquid inlet and the liquid outlet are formed in the cover plate and extend from the first cover plate side to the second cover plate side.

8. The apparatus according to claim 7, wherein the cover plate is formed of silicon; and the first cooling plate side is directly bonded to the first cover plate side by a second silicon-to-silicon bond.

9. The apparatus according to claim 4, wherein the cooling plate is formed of polycrystalline silicon fabricated from cast polycrystalline ingots.

10. The apparatus according to claim 4, further comprising:

- a pump;
- a liquid feed tube fluidly coupled between the pump and the liquid inlet; and
- a liquid exit tube fluidly coupled between the liquid outlet and the pump.

11. The apparatus according to claim 10, wherein the plurality of interconnected channels forms a channel network; and the channel network includes one pair of opposed channel segments and a plurality of parallel channel segments fluidly coupled between the opposed channel segments.

12. The apparatus according to claim 11, wherein the liquid inlet and liquid outlet are fluidly coupled at a pair of diametrically-opposed corners of the channel network.

13. A method comprising:

- providing an enclosing plate made of a first semiconductor material and a

cooling plate made of a second semiconductor material, the cooling plate having a first cooling plate side and a second cooling plate side;

- machining a plurality of interconnected channels into the first cooling plate side of the cooling plate; and

- heating the cooling plate to form a first semiconductor-to-semiconductor bond between the first cooling plate side and the enclosing plate to enclose the interconnected channels and to form a plurality of liquid-conducting passages.

14. The method of claim 13, wherein the first semiconductor material and the second semiconductor material are silicon.

15. The method of claim 14, wherein the enclosing plate is an integrated circuit (IC) die.

16. The method according to claim 15, further comprising:

- drilling a pair of liquid flow holes into the second cooling plate side to intersect with the interconnected channels so as to form a liquid inlet and a liquid outlet.

17. The method according to claim 16, further comprising:

- providing a pump and fluidly connecting the pump between the liquid inlet and the liquid outlet to form a closed loop circulation path for a cooling liquid.

18. The method according to claim 17, further comprising:

- sizing the width and length of the cooling plate to be substantially the same as the IC die.

19. The method according to claim 14, wherein the enclosing plate is a silicon cover plate and the method further comprises:

- providing an IC die;

- the heating of the cooling plate further includes forming a second silicon-to-silicon bond between the second cooling plate side and the IC die.

20. The method according to claim 19, further comprising:

- drilling a pair of liquid flow holes through the cover plate to intersect with the interconnected channels in the cooling plate to form a liquid inlet and a liquid outlet.

21. The method according to claim 20, further comprising:

- fluidly connecting a pump between the liquid inlet and liquid outlet to form a closed loop circulation path for a cooling liquid.

22. The method according to claim 21, further comprising:

- sizing a width and a length dimension of both the cooling plate and the cover plate to be substantially the same as a width and a length dimension of the IC die.

23. A system, comprising:

- an electronic assembly including an integrated circuit (IC) die having a substrate formed with a first semiconductor material; the electronic assembly further including a cooling device formed with a second semiconductor material and directly bonded to the substrate of the IC die; and the cooling device including a plurality of enclosed, interconnected liquid-conducting passages and a liquid inlet and a liquid outlet which are fluidly coupled to the plurality of liquid-conducting passages;

- an IC package having the electronic assembly mounted therein;

- a printed circuit board (PCB) having the IC package mounted thereon;

- a dynamic random access memory mounted on the PCB and electrically coupled to the electronic assembly; and

- an input/output interface mounted on the PCB and electrically coupled to the electronic assembly.

24. The system according to claim 23, wherein the IC die is a microprocessor; the PCB is a motherboard; and the input/output interface is a networking interface.

25. The system according to claim 23, wherein the first and the second semiconductor materials are silicon.

26. The system according to claim 25, wherein the cooling device includes a cooling plate having a first and a second cooling plate side with a plurality of interconnected channels being formed on the first cooling plate side; and an enclosing plate mounted to the first cooling plate side to enclose the plurality of interconnected channels and to form the plurality of liquid-conducting passages.

27. The system according to claim 26, wherein the enclosing plate comprises the substrate of the IC die; the first cooling plate side is directly bonded to the substrate of the IC die by a silicon-to-silicon bond; and the liquid inlet and liquid outlets are formed in the cooling plate and extend between the plurality of interconnected channels and the second cooling plate side.

28. The system according to claim 25, wherein the enclosing plate comprises a cover plate; and the second cooling plate side of the cooling plate is directly bonded to the substrate of the IC die by a first silicon-to-silicon bond.

29. The system according to claim 28, wherein the cover plate has a first cover plate side and a second cover plate side; the first cover plate side is attached to the first cooling plate side to form the liquid-conducting passages; and the liquid inlet and the liquid outlet are formed in the cover plate and extend from the first cover plate side to the second cover plate side.

30. The system according to claim 28, wherein the cover plate is formed of silicon; and the first cooling plate side is directly bonded to the first cover plate side by a second silicon-to-silicon bond.